PUBLICATIONS OF THE SCOTTISH COUNCIL FOR RESEARCH IN EDUCATION

III

CURRICULUM
FOR PUPILS OF TWELVE TO FIFTEEN YEARS
(Advanced Division)

Reprint No. 5

SCIENCE (Physical and Biological)

UNIVERSITY OF LONDON PRESS, LTD.
10 & 11 WARWICK LANE, LONDON, E.C. 4
1931

PRICE SIXPENCE NET

PUBLICATIONS OF THE SCOTTISH COUNCIL
FOR RESEARCH IN EDUCATION
III

CURRICULUM
FOR PUPILS OF TWELVE TO FIFTEEN YEARS
(Advanced Division)

Reprint No. 5

SCIENCE (Physical and Biological)

UNIVERSITY OF LONDON PRESS, LTD.
10 & 11 WARWICK LANE, LONDON, E.C.4
1931

PANEL ON SCIENCE (Physical and Biological)

PETER COMRIE, M.A., B.Sc., LL.D., F.R.S.E., F.E.I.S., Convener.

DAVID ANDERSON, M.A., B.Sc., F.E.I.S.
WILLIAM CAMERON, B.Sc., A.R.C.S.
F. A. E. CREW, M.D., D.Sc., Ph.D.
JAMES B. GUTHRIE, M.A., B.Sc.
Miss ISABELLA M. KING, B.Sc.
G. MACGREGOR, M.A., B.Sc., F.E.I.S.
JAMES A. MACKIE, M.A., B.Sc.
T. J. MACKIE, M.D., D.P.H.
G. A. SCOTT, M.A., B.Sc.
A. M. WATTERS, M.A., B.Sc., F.R.S.E.
JOHN WISHART, M.A., F.E.I.S.

Bureau Ednl. Psy. Research
DAVID HARE TRAINING COLLEGE
Dated 4/2/54
Accs. No. 212

Printed in Great Britain by
NEILL & CO., LTD., EDINBURGH.

SCIENCE

Introductory.—Science was introduced as a definite subject of the school curriculum about fifty years ago. Received at first with indifference and sometimes with active hostility, it has now reached its present position, where it forms an integral part of the curriculum of every properly organised school. The claims for its inclusion in the curriculum are analogous to those of other subjects —English, History, Geography, Languages. These subjects "are part of the equipment and preparation for life which we expect the school to give to its pupils so that they may play their part in the community as intelligent citizens, able to give efficient service, to appreciate and enjoy the beauty and wonder of the world in which they live, and to take delight in the wealth of culture in its many forms left to them by past generations."[1] Science takes its place side by side with these subjects as an essential element in a liberal education: "It affords a knowledge of certain facts and laws and an insight into methods and data peculiar to the domain of science which should be provided for every pupil."[2]

Science has a distinct practical value. We live in a scientific age. Recent developments in flying, in "wireless" and telephony, in the application of electricity to the lighting of houses and streets and to the

[1] J. Brown, *Teaching Science in Schools*, p. 3.
[2] *Ibid.*

driving of machinery, in the use of the internal combustion engine, and in medical science, hygiene, food production, and the welfare of mankind generally, render it essential that all boys and girls should have such an introduction to science as will provide them with an intelligent and appreciative outlook upon life.

The reasons which have led to the introduction of Science into the school curriculum determine to a large extent the nature and subject-matter of the Science Course. Science is taught because a general education is not complete if it does not include some knowledge of natural phenomena, of the physical laws and properties of matter, and of the application of scientific principles met with in everyday life.

The Science Course should not be planned on the assumption that pupils intend to pursue a career in which a special knowledge of some branch of the subject is essential. The vast majority of pupils will leave school at fifteen years of age, and the aim should be to include "a good general science course on broad humanistic lines which will be of value to all the pupils as a part of a sound liberal education." [1]

The scheme outlined in the following pages is intended for boys and girls from twelve to fifteen years of age. It is very comprehensive, and is not laid down as a hard-and-fast course to be followed in its entirety, but rather as a suggestive scheme indicating the spirit in which the subject should be taught, while leaving the teacher freedom to select and to elaborate those parts of the subject which have a local interest or which make a special appeal to the type of pupil under instruction.

[1] *Op. cit.*, p. 11.

It is thus elastic enough to allow teachers to select suitable matter for girls taking a domestic science course and it may also be adapted to pupils of slow development.

We are definitely of opinion that Biology should form part of the science instruction in all schools. This part of the scheme is meant to be a guide to what may be usefully taught in the subject. The aim has been to acquaint the pupil with broad biological principles and not merely to present collections of facts. The subject should not be regarded as a series of nature-study lessons. Technical phrases must necessarily be introduced, but these should be restricted to a minimum. It is important that the subject-matter should be based on observation and experiment.

Much of the study can be carried out with the help of a hand lens, while most of the material may be easily obtained throughout the year from garden, countryside, or shops. School aquaria and museums should be established wherever possible, and visits should be paid to Museums and Botanic and Zoological Gardens where these are conveniently situated. Excursions for the collection of plants and animals should be a regular feature of the school time-table.

In short, this part of the syllabus is intended to arouse an interest in living things, to exhibit the wealth and variety of organisms, to bring the pupil to realise the intensity of the struggle for existence, and to illustrate the numerous ways in which plants and animals "answer back" to the limitations of their environment.

A fairly detailed treatment of the sections on Astronomy, Geology, and Biology is presented in the appended scheme. Notes are, however, added to the sections on

Physics and Chemistry to indicate the extent to which these subjects are to be studied.

The time required for Science is a minimum of six periods per week, of which two should be devoted to Biology. This allocation of time need not entail the provision of more laboratory accommodation. For many years far too much formal and exacting experimental work has been required of pupils in science, with the result that the curriculum has been so circumscribed that pupils leave school at the end of a three years' course with little interest in, and often blind to, the wonders of the world in which they live, their natural curiosity unsatisfied, the development of plants and animals and the romance of the march of modern scientific discovery a sealed book to them.

When experimental work in Science was introduced into the schools the pendulum swung from the position where no such work was undertaken to the extreme position where nothing else was attempted and where the only aspects studied were those which lent themselves to precise measurement and quantitative manipulation. In this phase the broad humanising influence of the study of Science tended to be lost, and the time has come to redress the balance and recast the schemes, and, while granting due recognition to the claims of practical work, give pupils "a general knowledge of scientific principles and achievements in as wide a field as possible." [1]

[1] *Op. cit.*, p. 24.

SCHEME

First Year

Elementary Chemistry and Physics (Three Terms)

The three states of matter.

Simple illustrative experiments on Expansion of Solids, Liquids, and Gases.

Principle and use of thermometer—melting- and boiling-points.

Distillation—purification of a liquid and separation of a mixture of liquids.

Solution and crystallisation—purification of a solid and separation of a mixture of solids.

Diffusion of gases and solutions.

The Atmosphere.—Rusting of iron—active part of air. Combustion—Phosphorus, Magnesium, etc.

Work of Priestley, Lavoisier, etc.

Action of heat on substances to yield Oxygen.

Preparation and properties of Oxygen and Nitrogen.

Oxides.

From a consideration of the above experiments—

(*a*) distinguish physical and chemical changes ;
(*b*) define Elements, Compounds, and Mixtures.

Air Pressure.—Illustrative experiments using air and water pumps.

Head of liquid—simple barometer and its use.

Effect of pressure on boiling-point of a liquid.

Effect of pressure on gas—spring of the air.

Transfer of Heat:—Experiments illustrating the three processes.

Conduction, Convection, Radiation—applications.

Elementary Astronomy (First Term):

Ancient and modern views of Solar System—Copernicus, Galileo, etc.
The Sun—a star—distances in light years. Planetary system—relative positions, sizes, etc.
The Earth—rotation and revolution. Measure of time—day and night. Year (seasons).
The Moon—the month. Phases.
Eclipses of Sun and Moon.
Tides.

Elementary Geology (Second Term):

The Earth cooling from a hot gaseous state—solid crust—rocks—(*a*) igneous ; (*b*) sedimentary.
Earth movements—folding, landslide, volcano.
Weathering of rocks—water and carbon dioxide—solvent action. Rivers. Frost. Climate changes.

Soil.—Examination and separation of top-soil and sub-soil.

Clay, sand, grit, humus.
Properties of clay and sand with reference to the passage of air and water (springs). Effect of adding lime to clay.
Humus—leaf mould.
Peat—moorland—necessity for ditches.

Biology (Third Term):

Signs of Spring.—Reawakening of plant and animal life. Opening of buds. Lengthening of day. Increase in warmth of sun as affecting plant and animal life. Return of migrants.

A Simple Plant.—A complete plant to be examined to show root, stem, leaf, flower, and fruit.

(Note.—The functions of the various parts will be found as the result of experiments later in the course.)

Parts of a Flower.—A simple flower to be examined, and, as far as possible, the function of each part to be determined.

Visits of insects to flowers to get pollen and honey.

Insects.—Structure and life-history of an insect, *e.g.* butterfly or bee.

Relationship of insects to flowers. This will bring out ideas of pollination and how the flower is adapted for it.

Growth and Locomotion.—Development of Tadpole from an egg. External structure of a Fish to note how adapted for life in water.

(Whenever possible aquaria should be kept and general observations made on the movements and habits of animals.)

Earthworm.—External structure of an Earthworm to see how fitted for life in the soil.

Habitats of Animals.—An insect in the air ; a fish in water ; a frog, in water and on land; and an earthworm under the earth have now been studied.

On such lines as these it should be possible to show how various animals are adapted to cope with their environment and the struggle of fellows and foes.

Second Year

Chemistry and Physics (Three Terms)

Chemistry: Water.—Burning of a candle and ordinary combustibles—products, water and carbon dioxide.

Water an oxide—reduction by metals to form hydrogen.

Action of metals on the common acids.

Preparation and properties of hydrogen.

Composition of water.

Chalk.—Examination of chalk, marble, etc.—formation.
Preparation and examination of quicklime, slaked lime, and lime water.
Loss of weight when chalk is heated.
Preparation and properties of carbon dioxide.
Hard and soft waters. Builders' materials.

Physics.—(Each part of the subject to be introduced by considering common machines, physical phenomena, etc., and showing the necessity for establishing relation between forces, law of moments, principle of work, etc.)
Forces—equilibrium, moments.
Centre of gravity — density and principle of Archimedes.
Revision of fluid pressure.
Machines—levers, pulleys, wheel and axle, screw-jack.
Simple ideas of friction—lubrication.
Simple ideas of energy—heat, light, etc., as forms of energy.

Heat.—Revision of first year's work.
Heat a quantity—Specific Heat, Latent Heat.
Applications. Formation of water vapour.
Water vapour in atmosphere.

Biology (First Term):

Biology of Autumn.—Shortening of day.
Lowering of temperature.
Decreased activities of plants and animals.
Bird migration.

Fertilisation.—Recall lesson on insects carrying away pollen. Various other methods of carrying pollen. What happens to the pollen? Lead on to Fertilisation, which should be simply brought out as the result of observation and experiment on a simple

flower. (Pollen grains and development of pollen tube should be shown under microscope, if possible.)

Fruits and their Dispersal.—Formation of simple fruits.
Dispersal of fruits, by (1) wind; (2) water; (3) animals; (4) explosive mechanisms.
How each kind is adapted for dispersal.

Seed Structure.—Structure of a Broad Bean.
Conditions necessary for germination and growth.

Biology of Winter.—Behaviour of plants in winter—

1. Fall of leaf in deciduous trees. Fate of the fallen leaves.
2. Behaviour of evergreens.
3. Storage of food in underground parts, *e.g.* bulb, corm, stem, and root storage.
4. Production of seeds in annual plants.
   Bulbs should be planted in fibre in school, and pupils encouraged also to do this at home.

Behaviour of animals in winter—

1. Migration.
2. Hibernation.
3. Food storage and partial sleep, *e.g.* squirrel.
4. Change of colour.
5. Production of eggs.
6. Making the best of it.

Biology (Second Term):

Study of the Soil.—Revision of first year's work.

Kinds.—(1) Sandy; (2) clayey; (3) chalky; (4) humus soils. Their origin, advantages, and disadvantages from the point of view of plant growth. An ideal soil.

Analysis.—Mechanical separation of soils. Holding capacity of various soils. Estimate amount of

water, organic and inorganic materials, in various soils. Experiment to show that soils contain dissolved salts.

Gardening and Farming Operations.—Improvement of soils.

The Root.—Simple structure of a root. Root hairs. Kinds of root, *i.e.* tap and fibrous.

Osmosis and Root Pressure.—To be demonstrated.

Movement.—Response of the root to (1) gravity; (2) moisture; (3) light.

Transpiration.—Path of water up a stem to be shown. Value of water to a plant. Turgidity and wilting.

Cell Structure and Tissue.—Show under microscope a transverse section of any dicotyledon stem and of a tadpole to get simple idea of cellular structure and grouping of cells for particular work.

Respiration of Plants.—Meaning.

Show that roots, flowers, leaves, buds, and stems all breathe. Epidermis of leaf under microscope—stomata.

Respiration of Animals.—

1. Lungs.
2. Gills.
3. Cutaneous respiration.

Biology (Third Term):

Plant Feeding—Work of the Leaf.—Sources of carbon dioxide in the atmosphere and what becomes of it.

Making of Starch.—Test for starch.

Decolorise a leaf and show that starch is present.

Building up of starch by the plant. Conditions necessary for making of starch in the plant.

Stimuli and Movement.—Effect of heat and light on stems and leaves.

Climbing plants. Necessity for, and modes of climbing.

Transport and Storage of Food.—Where the food is taken. Food storage in root, stem, bulb, and seed.

Show presence of starch in all these.

Animal Feeding.—How animals obtain food.

Foods.—Value of foods.

Simple classification of foods. Food inter-relationships between plants and animals.

Flowers.—Pupils should be encouraged to collect flowers and note their adaptations to their habitats, and a special study made of (say) Sweet Pea, Wallflower, and Deadnettle.

Third Year

Chemistry and Physics (Three Terms)

Chemistry: Examination of carbonates in general, including washing-soda and baking-soda.

A simple study of some commercial processes, especially those associated with local industry, *e.g.* production of coal-gas, extraction of metals from ores, etc.

Some simple tests for the identification of the more common substances.

Characteristics of Foodstuffs and Textile Fabrics.

Physics: (These branches to be treated simply with illustrative experiments.)

Light.—Sources of light—velocity.
Reflection—mirrors.
Refraction—water, glass, lenses, prisms.
Optical instruments—camera, eye, spectacles, etc.
Colour—rainbow.

Sound.—Sources—transmission.
Velocity of sound.
Stringed and wind instruments.
Musical notes and noises.
Pitch—intensity—resonance.
The musical scale.

Magnetism.—Lodestone, artificial magnets.
Induction.
Terrestrial magnetism.
Mariner's compass.

Electricity.—Simple cell, use of accumulator and dry cell.
Conductors and insulators.
Effects of current—(*a*) heating and lighting; (*b*) chemical; (*c*) magnetic.
Electric bell, electro-magnets, motor and dynamo.

Biology (First Term):

Differences between Living and Non-living.—

1. Movement.
2. Respiration.
3. Nutrition.
4. Growth.
5. Irritability.
6. Reproduction and Death.

Differences between Plants and Animals.—From the plants and animals studied it should be possible to elicit the differences between plants and animals.

Classification.—Simple division of Animal Kingdom in regard to the main classes of Vertebrates and Invertebrates.

Amœba.—Study of Amœba under microscope. Asexual reproduction.

Salmon.—Life-history of the Salmon to show growth, metamorphosis, and change of habitat.

Eel.—Story of the Eel and its migration.

Bird Adaptation.—How a bird is fitted to live in the air.

Eggs.—Function, shape, colour.

Biology (Second Term):

Mammals.—Study of a Mammal, *e.g.* Rabbit, in conjunction with human body and its systems.

(*a*) Skeleton.
Knowledge of main parts of human skeleton.
Experiment to find percentage of organic and inorganic matter in bone, and the use of each.

(*b*) Digestion. Teeth and the alimentary canal. Simple experiments to be performed.

(*c*) Circulation and absorption.
Human blood to be shown under the microscope.

(*d*) Respiration.

(*e*) Parental care. Comparison with other animals.

Elementary Hygiene.—Impurities in the air and food and the necessity for clean, healthy living.

Nervous System.—Simple consideration of the brain and spinal cord and telegraphic system of the body.

Special Sense Organ.—The human eye.

During this term plant study should deal with irregular methods of feeding, *i.e.*—

Study of an insectivorous plant.
Study of a partial parasite, *e.g.* Mistletoe.
Study of a complete parasite, its characteristics and effect on host. Nodules on roots of Pea family.

(In rural areas Rotation of Crops may be usefully taken up here.)

Refer also to animal parasites.

Biology (Third Term):

Plant Ecology.—Elementary study of the relationship of plants to their environment and how they adapt themselves.

Growth Factors.—Effect on plant growth of—

1. Temperature.
2. Light.
3. Moisture.
4. Prevailing winds.
5. Soil.
6. Man.

Plants of Dry and Wet Areas.—Characteristics and adaptations of plants of dry areas.

Characteristics and adaptations of plants of wet areas.

Further Flower Study.—Further study of special flowers. Pupils should be able to recognise a few natural orders, *e.g.*—

Recognition of Families.—Buttercup family.
Wallflower.
Primrose family
Pea family.
Lily family.

Evolution.—Overcrowding and the Struggle for Existence.

How plants and animals survive.

Along these lines simple ideas of Heredity and Evolution may be discussed.

NOTES ON SCIENCE SCHEME

First Year

Elementary Chemistry and Physics:

Examine Bunsen Burner to understand how it "works."

$$\text{Ice} \underset{\text{cool}}{\overset{\text{heat}}{\rightleftarrows}} \text{water} \underset{\text{cool}}{\overset{\text{heat}}{\rightleftarrows}} \text{steam.}$$

Other examples, *e.g.* sulphur in test-tube.

Three States of Matter. — Solid, Liquid, Gaseous. Examples.

Effect of Heat on Solids.—(1) Ring and ball ; (2) compound bar ; (3) experiment to show force exerted during expansion and contraction.

Idea of the extent of expansion, *e.g.* 10 yards iron expands ½ inch when heated from ice temperature to steam temperature.

Application—railways, bridges, etc.

Effect of Heat on Liquids.—Expansion flask with water. Series of expansion flasks with different liquids.

Effect of Heat on Gases.—Expansion flask.

The Thermometer.—An example of an expansion flask—

Its use. (1) The temperature of air, water, body, etc.

(2) The temperature at which ice and wax melt.

(3) The temperature at which water boils.

Convey the idea of Latent Heat (general).

Find effect on Temperature of adding (*a*) sand or insoluble matter ; (*b*) salt or soluble matter.

Find the boiling-point of Methylated Spirit—Liebig's Condenser—*Distillation.*

Pupils distil salt water, dirty water, etc.

Separation of a mixture of liquids—application in industry.

Solution.—Common salt in water—saturated solution—crystals.

Soluble and insoluble substances—purify a solid, *e.g.* rock salt.

Crystallisation.

Other solvents—applications.

Solution of liquids and gases in liquids.

Rusting of Iron.—Increase in weight (use of balance).

Approximately one-fifth of air by volume used up.

No rusting in (*a*) dry air ; (*b*) water free from air.

Applications—Use of desiccator, of oil, of paint, etc.

Burning of Magnesium (and other metals).—Increase in weight.

Burning of Phosphorus.—Approximately one-fifth of air by volume used up.

Air made up mainly of (*a*) Oxygen—one-fifth (approximately) by volume—active ; (*b*) Nitrogen—four-fifths (approximately) by volume—inert.

Action of heat on Mercuric Oxide, Potassium Chlorate alone and with Manganese Dioxide.

Preparation and Properties of Oxygen.—Oxides—Carbon Dioxide—its presence in atmosphere.

Acid and alkaline solutions.

Work of Priestley, Scheele, Lavoisier.

Preparation and Properties of Nitrogen from the air by the removal of Oxygen.

From previous experiments distinguish—

(*a*) Types of changes (1) Chemical; (2) Physical. Give some everyday examples.

(*b*) Elements, compounds, mixtures—examples.

Air Pressure.—A number of simple experiments to show that air exerts pressure.

Head of liquid—balancing columns.

Experiment to measure pressure of atmosphere—simple barometer—Torricelli.

Use of Aneroid Barometer in mountaineering, aviation, and mining.

Experiment to measure pressure of gas supply using U-tube.

Pop-gun, bicycle pumps, etc., bottle with tube to water tap, etc., to show that "as the volume of gas increases, its pressure decreases, and *vice versa.*"

Effect of pressure on boiling-point of water—application—cooking.

Transfer of Heat.—Poker in fire, etc.

(*a*) Similar rods of different material.
(*b*) Rods of same material but different diameter. } Held in Bunsen flame.

Good and bad conductors—application.

Water a bad conductor—convection currents of water and air—ventilation, etc.

Radiation of heat from fire, sun, etc.

Hot-water system of heating.

Thermos flask.

Second Year

Chemistry:

Water.—Burning a candle, or coal-gas, in confined space. (1) Moisture ; (2) Carbon Dioxide.

Collect the moisture, show it is water by means of its boiling-point and the $CuSO_4$ test.

Water formed by combustion contains oxygen.

Reduction of water by Mg, Fe
Action of Na and K on water } Gas liberated—hydrogen.

Action of metals on the common acids—hydrogen from the acid, but not *always*.
Preparation and properties of hydrogen.
Diffusion of gases, balloons.
Water formed by hydrogen burning.
Electrolysis of water.

Chalk.—Examination of chalk and quicklime.
Percentage quicklime from chalk.
Marble and sea-shells, etc., treated similarly.
Action of acids on these substances.
Carbon dioxide.
Preparation and properties of carbon dioxide.
Action of CO_2 on lime.
Applications—builders' materials and formation of stalactites.
Hardness of water.

Physics:

(NOTE.—The various principles involved in the following portion of the scheme are much better examined by using larger masses than is customary.

The experiments on density, specific gravity, floating and immersed bodies should be carried out with large stones, blocks of wood, pound weights, etc., using suitable spring balances with large vessels for containing the fluid. Quite reliable numerical results are obtained by such means, and in the absence of the usual experimental detail the general conclusions to be drawn are much more obvious to the pupil.

Experiments on the measurement of Quantity of Heat, Specific Heat, and Latent Heat should be carried out with lumps of metal, *e.g.* half-pound weights of iron, brass, etc., and with copper cans of a capacity about one litre.

A steadily burning Bunsen can be regarded as supplying

heat at a uniform rate. For use in country districts there are oil burners on the market which adequately serve the same purpose.)

Forces.—Forces classified as pulling, pushing or twisting.
Forces cause, stop, or change motion.
Forces balanced by other forces, *e.g.* tug-of-war, hanging weight, etc.—tension, etc.—equilibrium.

Measurement of Force.—Rubber or spiral spring—spring balance.

Turning Power of Forces.—See-saw (adjustment of heavy and light weight by trial and error).
Experiment to find relation between weights and distances.

Moment of a Force.—Other illustrations.

Uniform rod suspended horizontally from two spring balances.	Note difference.
Non-uniform rod suspended horizontally from two spring balances.	

Find balancing point in the latter case—test by Law of Moments.

Centre of Gravity.—Find weight of body—steelyard.
Experimental method of finding position of Centre of Gravity.
Stability.
Weights of equal-sized cubes or cylinders of the same and of different materials—idea of Mass and of Density.
Weights of equal volumes of different liquids (using burette).
Water—the standard for density—relative density.
Volume and density of an irregular solid (volume by displacement).

Fluid Pressure.—Revision of first year's work.

Swimming, floating, cork released from bottom of liquid column, sinking body, etc. — *upward thrust of liquid.*

Ship leaking—*sideways thrust.*

Experiments to show that a liquid exerts a force in all directions and the force increases with the depth (divers).

Head of liquid—siphon, water supply, building of reservoirs, etc.

Similarly buoyancy in gases—balloons.

Illustration in laboratory—volume and density of irregular solid by principle of Archimedes.

Floating body—relation between weight of body and weight of water displaced — hydrometer —relative density of liquids.

Application—tonnage of a ship—Plimsoll line.

Machines.—Examples—purpose—

(1) Raising heavy weight by small force.
(2) Applying force at more convenient position.
(3) Transmission of power.

From above discussion select an order of treatment—

e.g. Experiment to measure the advantage in the use of lever (moments)—types of levers—examples.

Experiment to measure the advantage in the use of wheel and axle—examples—capstan, bicycle, mangle, etc.

Use of fixed pulley to change direction of force.

Experiment to find advantage in use of single movable pulley.

Application — use of pulley-block, crane, etc. Similarly, use of inclined plane and screw-jack, etc.

N.B. (1) In these machines the small force moves through a greater distance than the large force.

(2) More work "put into" than "got out of" the machine.

Friction.—Difficulty in pulling cart on road, beach, etc. Difficulty in walking on frozen roads, etc.

Experiment.—Use spring balance to pull a block of wood along different surfaces, *e.g.* floor, table, glass—note differences. Force used here is not overcoming weight of body (vertically downwards) but acting against friction.

The friction depends on the surface (rough or smooth) and on pressure between the surfaces.

Work must be done in machines to overcome friction—heat generated—and necessity for lubrication (use of ball-bearings).

Consider a "frictionless world" to show important part friction plays, *e.g.* in walking, etc.

Sand on rails in frost.

Brakes and screws, etc.

In above, pupils acquire a general idea both of machines doing work, and work being done on machines. The idea can be extended by reference to windmills, water-wheels, etc., so that a body falling or moving is capable of doing work—Energy.

Some work was used up in overcoming the friction of parts of the machine and heat was produced—Heat a form of Energy.

Simple illustrations from steam engine, etc.

Transformation of Energy—other illustrations in Light, Electricity, Biology, etc.

Heat:

Revision of first year's work. Cooling water below 4° C.

Peculiar behaviour of water. Effect on aquatic life.

Experiment.—Into equal weights of cold water at same temperature pour—

(*a*) Unequal weights of hot water at same temperature ;
(*b*) Equal weights of hot water at different temperatures ;
(*c*) Equal weights of different substances at same temperature ;

and note resulting temperatures of the mixtures.[1]

The heating effect depends upon weight, temperature, and material.

Unit of Heat, Calorie, B.Th.U., Therm.

Experiment.—To find quantity of heat given out by 1 gram of different substances cooling through 1 centigrade degree, *e.g.* turpentine, glass or aluminium, copper or brass, lead, hence the idea of *Specific Heat.*

Application—Hot-water system of heating.

General idea of *Latent Heat* already noted in first year.

Experiments on Latent Heat, using ether, ammonia, etc.

Principle of refrigerators, ice-making, etc.

Experiment.—Calibration of Bunsen Burner—number of calories supplied per minute by bunsen.

Experiment.—Find *roughly* the Latent Heat of steam.

[1] See note on p. 20.

Experiment.—Find *roughly* the Latent Heat of fusion of ice (quantity of ice adjusted to cause fall in temperature from 20° C. to 5° C.). *Omit* corrections for cooling of vessel.

Freezing, and thawing.
Expansion of water on freezing—
Burst pipes, soil, rocks, etc.
Evaporation and Condensation—
Water, vapour in atmosphere—dew, fog, etc.

Third Year

Chemistry:

Revision of chemistry of chalk.
Examination of soda ash, washing-soda, baking-soda.
Examination of other carbonates (by different members of class)—general properties of carbonates.
Destructive distillation of coal and wood—

Products (1) Inflammable gas.
(2) Watery liquid.
(3) Tarry liquid.
(4) Solid residue.
General examination of these and an indication of their uses.

Same process on large scale—gasworks (visit).
Some attention should be given to industrial development of some of the by-products, *e.g.* coal tar—dyes, perfumes, etc., and ammonium sulphate as a fertiliser—importance of nitrogen—synthetic ammonia process.
The same experiments of distillation with—

(*a*) Parts of plants
(*b*) Foodstuffs
(*c*) Horn, hoof, hair
to show similarity of composition—carbon cycle.

Metals.—Not found in pure state—as ores, *e.g.* oxides, carbonates, or sulphides, along with other metals and clay.

Examination of samples of ores and use of blow-pipe and charcoal block in the identification of such samples.

Similar process on manufacturing scale—

e.g. Roasting ore to get oxide.
Reduction of oxide with coke—blast furnace.
Purification of metals by electrolysis.

A few metals may be considered—

e.g. Iron—Pig iron—properties and use.
Wrought iron—properties and use.
Steel—properties and use.
Steel alloys—nickel, manganese, etc.

Similarly copper—brasses and bronzes—uses.
Aluminium—thermite—uses.

Clay—mainly an aluminium salt—porcelain, etc.

Sand—quartz, etc.—an oxide—heat sand with soda ash on platinum wire—glassy bead—sodium silicate (water glass)—glass manufacture.

Foodstuffs and Textile Fabrics.—The examination of the various foodstuffs and textile fabrics provides work of the greatest interest to the pupils, especially to girls.

Examination of Foodstuffs.—Simple experiments to illustrate the properties of starch, dextrin, the sugars, and cellulose—use of iodine to distinguish dextrin and starch. Simple experiments to illustrate the process of fermentation—action of saliva and yeast. Use of microscope to distinguish the characteristic forms of starch grains as found in the potato, wheat, maize, rice, tapioca, sago—hence examination of flour from various sources—water-absorbing capacity of flour—gluten content.

Detection of impurities in flour and other foodstuffs. Action of baking-soda, cream of tartar, and baking-powder.

Functions of Food.—General composition—starch, protein. Food as a fuel—relative advantages of various foods. Milk. Micro-organisms—very simple experiments to illustrate behaviour of moulds and common bacteria leading to causes of putrefaction, thence to action of disinfectants, deodorants, antiseptics, and preservatives. Sterilisation.

Textile Fabrics.—Use of microscope to study characteristic forms of the various animal and vegetable fibres—cotton, flax, linen, hemp, jute, wool. The knowledge acquired should be applied to the examination of specimens of different kinds of cloth.

Physics:

Light:

Light and darkness—luminous and non-luminous bodies.
Objects seen by direct or reflected light.
Sun—source of light.
Light radiated in straight lines.
Velocity of light.

Reflection of Light from a Plane Mirror:

Type of Image—direct experiments, not drawings, to show type of image formed by—

(*a*) Plane mirror—erect, same size, same distance, laterally inverted.
(*b*) Convex mirror—erect, diminished (use in motors, etc.).
(*c*) Concave mirror—inverted or erect, according to position.

Refraction.—Coin in water, Stick in water — explain by diagram.

Reading print direct and through thick glass.

Total internal reflection—round-bottom flask half full of water.

Objects viewed through a prism.

Application—Lighting underground passages.
Periscopes.
Mirage.

Objects viewed through (*a*) convex, (*b*) concave lens.

Application in Instruments.—

Camera.
Eye, spectacles.
Magnifying-glass.
Principle of telescope, microscope, field-glasses.
Optical lantern, and cinematograph.

Composite Character of White Light.—

Blurred image in a lens.
Newton's work—spectrum.

Sound:

Sound provides ample material for experiments and demonstrations certain to create interest in the minds of boys and girls. There is no necessity to use much mathematics.

The following is a brief synopsis of a suggested course in Sound:

Sound associated with movement; silence with perfect stillness; the ear—a special organ of the body for the identification of sound.

Sound created by a sudden movement; an explosion; a burst paper bag, etc.; an extra pressure created; transmitted; windows broken during gun-fire, etc.

This extra pressure is very small in case of ordinary sounds; pressure gauges useless; sensitive flames required; experiments with sensitive flames.

Sounds: Musical and Other.—Former created by regular succession of pulses; strips of steel held in vice; teeth of saw; hand-saw; circular saw; toothed wheel on rotating spindle; syren (or devil whistle); lead up to pitch.

Pitch.—Tuning-fork with stiff bristle fastened to one prong held against revolving smoked gramophone plate, or falling glass plate; approximate measurements may be made with gramophone.

Pitch and Loudness.—Loudness evidently due to magnitude of movement; illustrate with fork.

Transmission of Sound. — Obviously transmitted through air, also through solids; string telephone, or long length of railings in park; submarine signalling; earth signalling; plumber listening for leakage in water-pipe.

Does not travel through vacuum; experiment with toy bell in flask exhausted of air.

Velocity of Sound.—Observations on distant gun-fire; on distant railway engine whistle.

Method of Transmission.—Illustration of two boats on motionless sea; speaker in large hall; no mass movement of air from speaker to audience; waves.

Experiment. — Long $\frac{1}{4}$-inch rubber cord, about 12 to 15 feet, one end fastened; jerk other end up and down; note pulse travelling; send series of pulses; note wave form; specially note nodes; simple ideas of wave motion; and obvious relation that must exist between n, number of pulses, and l, wave-length; $v=nl$.

Resonance.—Introduce by example of heavy pendulum set in motion by properly timed taps. Columns of air in tubes. Tuning-fork and water in long tubes —use a burette.

Experiment.—Find velocity of sound in air.
A series of test-tubes in stand; hence use of resonance box in musical instruments.

Stretched Wires.—Simple sonometer experiments, leading up to violin, etc.

Musical Instruments.—Simple lessons on the various types; methods of producing the vibration and the resonance.

The Ear.—Observe the power of analysis; of distinguishing the various instruments or vocalists even when producing same pitch; contrast with eye.

Two Sounds together.—Two equal forks on resonance box, or two singing flames. With forks, load a prong of one; with singing flames, glass tubes two feet long, one inch diameter; paper collar on one.

Observe *beats;* then observe two distinct notes; discord evidently produced by *beats;* analogy of flickering light.

Combination of Sounds.—On blackboard draw wave form, then same form of half wave-length; then draw result of adding both. Note result is also wave form; physical parallel; one sound two or more notes; harmonics. Idea that the presence or absence of these harmonics may explain quality of note. Intervals; rates of frequencies; pitch.

The Simple Musical Chords.—The octave; no possible discordant harmonics, hence octave perfect accord or consonance. The fifth almost as good; also fourth; then the third. Start with note (say)

frequency 200 ; write down harmonics 200, 400, 600, 800, 1000, 1200. We get notes 200, 250, 300, 400 ; so we get d, m, s of frequencies in ratio 24 : 30 : 36. Build same chord on soh, and with same ratios we get s : t : r. Build same chord on fah, the fourth ; we get f : l : d—and so get

d : r : m : f : s : l : t : d with ratios
24 27 30 32 36 40 45 48.

Various Sounds.—Sounds of country; town; insects; birds; telephone; etc. Methods of production.

PUBLICATIONS OF THE SCOTTISH COUNCIL FOR RESEARCH IN EDUCATION

I. SCOTTISH SPINNING SCHOOLS
By IRENE F. M. DEAN. 5s. net.

II. EDUCATION IN ANGUS
By J. C. JESSOP, M.A., Ph.D., F.R.Hist.S. 5s. net.

III. CURRICULUM FOR PUPILS OF TWELVE TO FIFTEEN YEARS (Advanced Division). 5s. net.

REPRINTS OF SUBJECT REPORTS
6d. *each net*

1. ENGLISH
2. HISTORY
3. GEOGRAPHY
4. MATHEMATICS
5. SCIENCE (Physical and Biological)
6. MUSIC
7. ART AND CRAFTSMANSHIP
8. PHYSICAL EDUCATION
9. DOMESTIC ARTS AND CRAFTS
10. TECHNICAL SUBJECTS
11. COMMERCIAL SUBJECTS
12. RURAL SUBJECTS
13. LANGUAGES

UNIVERSITY OF LONDON PRESS, LTD.